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INTERCEPTION AND JAMMING OF BISTATIC/MULTISTATIC RADAR

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ABSTRACT: The paper briefly presents the fundamental concepts, models, and features of bistatic/multistatic (B/M) radar. The concepts of multisensor data fusion are described. The correlation identifying method of radar and communication interceptor using both sensors with data correlation processing is described in details. Computer simulation results show that this method is feasible. Finally, the methods of jamming B/M radar is described.

Key words: bistatic/multistatic radar; electronic warfare; multisensor data fusion; communication link; correlation identification

With rapid development of electronic warfare, the so-called four threats to radar and other electronic air defense systems have appeared; the four threats are the anti-irradiation missile, the concealed target, electronic comprehensive jamming and low altitude breakthrough. These threats directly eliminate the effectiveness of air defense systems using primarily a single-base radar, thus threatening the survivability of the air defense system and national defense security. Thus, four countermeasures coping with these four threats are required for a modern air defense system. Therefore the B/M radar re-emerged in the midseventies at a new level of technology. Centering on the four countermeasure capabilities, gigantic progress and major breakthroughs on concepts, theories, methods and technology have been attained. The B/M radar technology has advanced to a new application stage. With re-emergence of B/M radar, its superior four countermeasure features induce a new challenge to electronic countermeasures. It is required that an electronic warfare system can effectively detect and jam the B/M radar.

Reconnaissance of the B/M radar is against its transmitter (T) station and receiver (R) station. Conventional radar reconnaissance techniques can detect T stations. However, conventional techniques can not cope with reconnaissance of the R station due to the absence of radar irradiation. This is considered to be a difficult problem because the R station is considered as silent and not detectable. Moreover, due to the confidentiality of this technology, no reports abroad have been seen for two decades since the re-emergence of B/M radar. This article presents methods of preliminary determination of B/M radar and the related identification methods by applying the concept of data fusion with multi-sensors.

I. Fundamental Concepts and Reconnaissance Regime of B/M Radar

The B/M radar is a system with deployment of T and R stations long-distances apart from each other. The four countermeasure features of B/M radar are attained due to long-distance deployment and the complex working regime of T and R stations.

Based on different sites in air space for T and R stations of B/M radar, the basic models of B/M radar can be divided as follows:

Long base type (land to land type) -- Both T and R stations are sited on land.

Air base type (air to air type) -- both T and R stations are situated in air or in outer space, such as airborne or satellite-borne.

Hybrid type (air to land type, or land to air type) -- T and R stations are sited on land, in air, or in outer space.

Based on different base line (the connecting line between T and R stations) status, the B/M radar can be divided as follows:

Fixed base-line type -- the relative positions of T and R stations are fixed with fixed length and base line orientation, such as land-base type or synchronous satellite-borne type.

Variable base-line type -- there is relative motion between T and R stations with continuous variation of base-line length and orientation, such as air-borne type or satellite-borne type.

There are other feature division methods according to other aspects; such as different relationships of relative position on boundaries between T and R stations on the one hand, and air defense territory on the other. Another division is the R advanced type and T advanced type. There are also other types.

Normal operation of B/M radar is to accomplish fundamental missions of radar. First of all, three major synchronizations (on space, time as well as frequency and/or phase) should be accomplished between T and R stations.

With respect to single-site radar, owing to the same site for T and R stations with shared antenna for transmitting and receiving, the receiving wave beam of R station coincides with the transmitting wave beam of T station. Thus, the irradiating air space of the T wave beam is also the air space of the receiving wave beam of the R station. All targets irradiated by

T wave beam can have their echo received by the R station receiver within its sensitivity limiting range, thus naturally accomplishing space synchronization between T and R wave beams. Moreover, due to same site for T and R stations, the receiver can very easily accomplish synchronization from information of time synchronization as well as frequency and/or phase synchronization.

With respect to B/M radar, since T and R stations are separated at long distances with T and R antennas, it is possible that T and R antenna wave beams intercept or not intercept in space. Only such targets within the intercepting air space of T and R wave beams within the sensitivity limit range for R station receiver, echo of such targets can be detected. Otherwise, the echo can not be detected. Therefore, to enable monitoring of the assigned air space by B/M radar, space synchronization should be accomplished on certain rules in the space search process of T and R wave beams. Generally, information of T wave beam orientation angle is sent toward the R station through a specific data communication link by the T station. Then, the synchronizing operation can be conducted by R wave beam according to certain rules. As revealed by a number of new research papers on B/M radar, there is an optimal scheme, the so-called pulse chasing technique, of effective and power economizing method on space synchronization.

Similarly, since the T and R stations of B/M radar are sited long distances apart, R station is unable to conveniently attain the necessary time synchronization as well as frequency and/or phase synchronization for coordinated operation. These two synchronizations can be attained from highly stable atomic clock with timing calibration set up at T and R stations. Or, a specific data communication link sends a synchronization signal from T to R stations. Besides, for sufficiently utilizing equipment in order to obtain various possibly attained data, a greater number and more precise signals can be extracted via data fusion. In addition, by utilizing performance compensation of B/M radar and single-base radar, the new research trend is to develop a hybrid system of single-base and B/M radars. In other words, the T station of B/M radar is a single-base radar. Hence, when the three above-mentioned synchronous signal data are sent from T station (it is also called T-R station here) to R station via data communication link, T station also sends target signals and other control signals and data.

With respect to targets to be detected, T station of B/M radar only requires to provide radar scanning to the assigned air space to let R station directly attain the situation information of the air space. The R station needs to send target information, other data and control signals via specific communication links on the following occasions: to send information on air space to the T station; to adopt anti-jamming measures of rapid changing parameters (such as rapid changing frequency) for remote control of T station by R station, which is under electronic jamming; according to information in the air space, an assigned T station only searches and scans a particular sector-shaped air space; or to send real-time information on air space to the command center. This explains that R station of B/M radar is (so-called) silent with respect to radar electromagnetic irradiation; this can not be detected with the traditional radar reconnaissance technology. However, with respect to communication irradiation and other unintended irradiation, R station is still an open electromagnetic system. Hence, reconnaissance of B/M radar R station can be executed via communication link irradiation and other unintended irradiations.

II. Fundamental Concepts of Multisensor Comprehensive Electronic Warfare System and Data Fusion

With rapid development of military electronic technology and weapon systems, the military battlefield has evolved from the past concept of single weapon against single weapon, to systems against systems or network against network. The battlefield has evolved into an integrated comprehensive electronic warfare system of detection and anti-detection, reconnaissance and anti-reconnaissance, jamming and anti-jamming, as well as destruction and anti-destruction. This involves a defense system, and also an offense system. This is a multi-terminal automated system including different types of sensors, comprehensive information processors and different types of execution components. Fig. 1 shows a comprehensive electronic warfare system with concentrated information processing.

Sensors include various types of radar systems, passive detector and friend-or-foe detector, among others. Execution systems include various types of ECM, ECCM, guidance weapons, directed energy weapons, and electromagnetic guided missiles, among others. These devices may operate on the land, on the sea, in the air, under the water, and in outer space. In the frequency domain may include sound, electricity, infrared and visible light, among others. In functions, included may be detection and anti-detection, reconnaissance and anti-reconnaissance, jamming and anti-jamming, destruction and anti-destruction, communication, navigation, friend-or-foe recognition, guidance, display of battlefield situation, among others.

The core of the comprehensive electronic warfare system is the comprehensive signal processing, which is multi-sensor data fusion processing. Its structure could be concentrated or scattered. The types of signal processing could be stationary or mobile types. The processing scale could be at the platform stage, theater stage, or global stage (including outer space). The processing method could be data stage comprehensive processing type, file stage processing type, or hybrid processing type.

According to the above-mentioned reconnaissance regimes of B/M radar, at least two of the following types of passive detection sensors should be applied: radar reconnaissance and communication link reconnaissance. Of course, other reconnaissance sensors may be added to enhance reliability of reconnaissance identification by B/M radar.

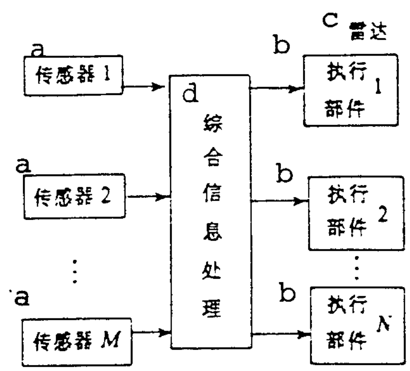

Fig. 1 Comprehensive System of Electronic Warfare

Key: a - Sensor; b - Execution component; c - Radar; d - Comprehensive signal processing

III. Principle and Method for Reconnaissance and Identification by B/M Radar

Assume that same data format and code rate are applied for communication links of T and R stations of B/M radar, and the unified geography reference coordinate system is adopted for the related geometric position parameters of the target as well as T and R stations; then according to the above-mentioned contents of the communication link of B/M radar, the communication link signal $S_1(t)$ of T station can be expressed as

$$S_1(t) = D_T(t) + T(t) + O_1(t) \tag{1}$$

In the equation, $D_T(t)$ is data of orientation angle signal of T wave beam; $T(t)$ is target data; and $O_1(t)$ is signal data of time base, frequency (and/or phase), control and others. Then the communication link signal $S_2(t)$ of R station is

$$S_2(t) = T(t) + O_2(t) \tag{2}$$

In the equation, $O_2(t)$ is other data of R station.

From Eqs. (1) and (2), if self-correlation processing is conducted for scanning cyclic lag of T wave beam with respect to $S_1(t)$, and cross-processing is conducted with respect to $S_1(t)$ and $S_2(t)$, the target signal can be detected. However, the target signal can be detected with cross-correlation processing with respect to $S_1(t)$ and $S_2(t)$. By utilizing these features as well as cross-correlation processing of geometric position and code rate, the B/M radar can be detected and identified.

Fig. 2 shows a flow-chart block diagram for reconnaissance and identification with B/M radar. Assume that radar description word (RDW) and communication description word (CDW) are obtained with radar reconnaissance and communication reconnaissance. Here, RDW and CDW are different from EDW (emission description word) as traditionally used for the description word of the irradiation source. Besides including contents of EDW, RDW also includes T wave beam orientation angle data, target data, geometric position data, and others. In addition, CDW includes geometric position data and code rate data, among others.

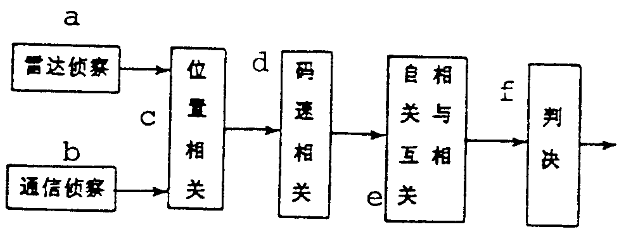

Fig. 2 Flow Chart Diagram of B/M Radar Reconnaissance Identification

Key: a - Radar reconnaissance; b - Communication reconnaissance; c - Position correlation; d - Code rate correlation; e - Self correlation and cross correlation; f - Determination

The correlation identifying methods of B/M radar are as follows:

(1) Pick transmitting station as T_0, described by radar RDW for correlation processing of code rate to conduct space correlation processing (which is the geometric position correlation processing) with one after one communication station described by all detected CDW. Thus, pick up communication station (marked as C_0) at the same position as T_0.

(2) Use C_0 as reference of code rate to conduct code rate correlation processing with such communication station described by other CDW. Thus, find out such communication station (marked as C_i, i = 1, 2, ..., K) with same code rate as C_0 but without radar T station at its site. Other stations are dropped.

(3) With respect to C_0 data, self-correlation processing is conducted for scanning cycle T_s time lag of antenna wave beam at T_0 station. If the wave-beam orientation angle signal of T station is detected, then T_0 is considered as transmitting station of a particular B/M radar, and C_0 its communication link,

marked as $M_{C0}=1$. Otherwise, mark $M_{C0}=0$.

(4) With respect to time lag T_s, self-correlation processing is conducted to C_i (i=1, 2, ..., K), which has same code rate as C_0. If target signal is detected, then C_i is considered as the receiving station of T_0, marked as $M_{Ci}=1$. Otherwise, mark $M_{Ci}=0$.

(5) Cross correlation processing is conducted for C_0 and C_i. If target signals are detected, then C_0 and C_i are pairing, marked as $M_{C0Ci}=1$. Otherwise, mark as $M_{C0Ci}=0$.

(6) Determine identification of B/M radar as follows:

i. If $M_{C0}=1$, $M_{Ci}=1$ and $M_{C0Ci}=1$, then C_0 and C_i are communication links of B/M radar; T station of B/M radar is at T_0 or C_0, and the corresponding R station is at C_i.

ii. If $M_{C0}=0$, then T_0 is single-base radar.

iii. If $M_{Ci}=0$, then C_i is a general communication station.

Pick another RDW as T_0. Repeat the above-mentioned steps; we can identify T and R stations of all B/M radars.

Conduct computer simulation of the above-mentioned methods, the result reveals that the correlation identifying method of B/M radar mentioned in the paper is feasible.

IV. Jamming Methods on B/M Radar

Beginning from features of long-distance apart between T and R stations of B/M radar, there are reconnaissance identifications of radar and the communication link. Correspondingly, jamming of B/M radar is done in two ways: jamming of radar and of the communication link.

4.1 Jamming of radar

Apparently, based on accomplishing reconnaissance identification of B/M radar, directional jamming can be conducted at the R station with the traditional and the most recent radar jamming techniques.

In the current trend of developing single- and dual-base hybrid B/M radar with T-R and R systems, besides the execution of jamming B/M radar by jamming its R station, jamming of the T-R station can be used to accomplish jamming on the single-base radar.

A great amount of technical resources have been poured in by Western Powers to develop super jammers, microwave bombs and electromagnetic missiles; at present, peak power of tens to thousands of megawatt has been reached for super jammers; the energy of a single pulse is between one to upwards of a hundred kilojoules, capable of rendering destructive damage to power or energy components of the radar receiver. Besides shutting off the receiver with TR switching spark on the receiver of T-R station for single-base radar, intensive jamming of the stationary wave of the receiver can be brought about. In addition, intensive jamming can be made by sending a microwave bomb to the R station, or launching of an electromagnetic missile with high propagation rate.

4.2 Jamming the communication link

As mentioned above, the B/M radar needs to send, via the communication link, three major signals: synchronizing, target and other controls. Hence, by jamming the communication link of B/M radar, we can demolish its normal operation, disturb the target data and various control signals.

Besides adopting techniques of communication countermeasures to jam the communication links, it is also necessary to develop jamming techniques of the synchronizing signal, target data and control signals. This also sufficiently reveals that a new route (jamming of communication links) is provided for electronic jamming besides enhancing the four countermeasure capabilities of B/M radar with B/M based and complicated operation regimes.

V. Conclusions

Beginning with operation features of B/M radar, this article abolishes the traditional concept that B/M radar can not be detected, by proposing the use of data fusion reconnaissance with correlation identifying method of the B/M radar with two sensors: radar and communication. In addition, four countermeasure capabilities of B/M radar are revealed. Another method of jamming the communication link is a new approach of electronic jamming.

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